CLAIMS

What is claimed is:

1. A torque sensing apparatus for picking up a magnetic flux flowing from edges of a magnetostrictive material disposed on a shaft, said apparatus comprising:

a first flux collector and a second flux collector spaced from each other and extending annularly around the shaft to define a gap therebetween;

a first fluxgate connected to said first flux collector at one end and to said second flux collector at the other end;

a first excitation coil wound about said first fluxgate; and

a feedback coil positioned in said gap such that said feedback coil is wound within said flux collectors, said first fluxgate, and said excitation coil.

2. An apparatus as set forth in claim 1 further including a second fluxgate connected to said first flux collector at one end and to said second flux collector at the other end.

3. An apparatus as set forth in claim 2 further including a second excitation coil wound about said second fluxgate.

4. An apparatus as set forth in claim 3 wherein said first and second flux collectors, said first and second fluxgates, and said first and second excitation coils are constructed of a high-permeable material.

5. An apparatus as set forth in claim 4 wherein said first and second excitation coils are connected in series.

6. An apparatus as set forth in claim 3 further comprising a detection circuit for determining a torque applied to the shaft.

7. An apparatus as set forth in claim 6 wherein said detection circuit further includes a voltage source for applying a voltage to said first and second excitation coils at a first frequency.

8. An apparatus as set forth in claim 7 wherein said detection circuit further includes a frequency doubler for doubling said first frequency to a second frequency and for producing an output signal relating to the voltage sensed at said second second frequency across said feedback coil.

9. An apparatus as set forth in claim 8 wherein said detection circuit further includes a lock-in amplifier for receiving signals related to a second harmonic voltage waveform on said feedback coil and for receiving a reference signal from said frequency doubler.

10. An apparatus as set forth in claim 9 wherein said detection circuit further includes a voltage to current converter configured to receive said output signal and

convert it to a current wherein said current in said feedback loop is driven to balance the flux that is applied to said first fluxgate and said second fluxgate.

11. An apparatus as set forth in claim 3 further including a shield positioned about said first and second flux collectors, said first and second fluxgates, said first and second excitation coils, and said feedback coil to block magnetic interference.

12. An apparatus as set forth in claim 3 wherein said first and second flux collectors, said first and second fluxgates, and said first and second excitation coils are integrally formed as a sleeve unit.

13. An apparatus as set forth in claim 12 wherein said sleeve unit is freely rotatable about the shaft.

14. An apparatus as set forth in claim 3 wherein said first and second flux collectors, said first and second fluxgates, said first and second excitation coils, and said feedback coil are integrally formed as a sleeve unit.

15. A torque sensing apparatus for picking up a magnetic flux, said apparatus comprising:

a shaft;

a magnetostrictive material disposed on said shaft;

a first flux collector and a second flux collector spaced axially from each other along said shaft and extending annularly around said shaft to define a gap between said shaft and said first and second flux collectors;

a first fluxgate connected to said first flux collector at one end and to said second flux collector at the other end;

a first excitation coil wound about said first fluxgate; and

a feedback coil positioned in said gap such that said feedback coil is positioned between said magnetostrictive material disposed on said shaft and said flux collectors, said first fluxgate, and said excitation coil.

16. An apparatus as set forth in claim 15 further including a second fluxgate connected to said first flux collector at one end and to said second flux collector at the other end.

17. An apparatus as set forth in claim 16 further including a second excitation coil wound about said second fluxgate.

18. An apparatus as set forth in claim 17 wherein said first and second flux collectors, said first and second fluxgates, and said first and second excitation coils are constructed of a high-permeable material.

19. An apparatus as set forth in claim 18 wherein said first and second excitation coils are connected in series.

20. An apparatus as set forth in claim 17 further comprising a detection circuit for determining a torque applied to the shaft.

21. An apparatus as set forth in claim 15 wherein said magnetostrictive material is applied by spraying.

22. An apparatus as set forth in claim 15 wherein said magnetostrictive material is applied by thermal spraying.

23. An apparatus as set forth in claim 15 wherein said magnetostrictive material is applied by kinetic spraying.

24. An apparatus as set forth in claim 15 wherein said magnetostrictive material is further defined as including magnetostrictive particles selected from one of iron, iron alloys, ingot rare earth composites, nickel, and terfenol.

25. An apparatus as set forth in claim 24 wherein said magnetostrictive material is further defined as including magnetic particles with coercivity selected from $AlNiCo_5$ magnets and melt spun terfenol.